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# TUBEWORMS (SERPULIDAE, POLYCHAETA) COLLECTED FROM SEWAGE OUTFALLS, CORAL REEFS AND DEEP WATERS OFF THE HAWAIIAN ISLANDS, INCLUDING A NEW *HYDROIDES* SPECIES

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## ABSTRACT

Quantitative benthic samples collected near sewage outfalls off Oahu contained two species of small, fragile serpulid tubeworms previously unknown from Hawaiian waters. One is a new species of *Hydroides* without an opercular funnel, the other is *Josephella marenzelleri*, a broadly distributed but easily overlooked serpulid. Retrieval of these species is attributed to the use of a Van Veen grab and elutriation and sieving to separate the polychaetes from the sediment. Another unrecorded small serpulid species, *Rhodopsis pusilla*, was found growing on a hard foliaceous sponge, in a cave, on a shallow reef off the Kona coast of Hawaii. Lava rocks collected with a submersible off S.E. Oahu (330 m depth) have yielded another little known serpulid species, *Filogranula gracilis*.

A new species and five new records of serpulid tubeworms from the Hawaiian Islands are described. The new *Hydroides* species occurs at depths of 70 m on coral sand off the south shore of Oahu. Specimens were first collected during benthic sampling for infaunal invertebrates near the Sand Island sewage outfall in September 1986 and subsequently at the same location and at Barbers Point a year later. Another small serpulid, *Josephella marenzelleri* Caullery and Mesnil, 1896, was found at the same outfalls in 1987, and was more abundant and widespread than the *Hydroides* n. sp. A third species, *Rhodopsis pusilla* Bush, 1905, was growing on a sponge in a cave on the reef off the Kona, Hawaii coast. A deep sea species, *Filogranula gracilis* Langerhans, 1884, was collected on lava rocks from 330 m off S.E. Oahu with large numbers of the serpulids *Spirobranchus latiscapus* Marenzeller, 1885 and *Vermiliopsis infundibulum* (Philippi, 1844).

Hawaiian deep water suspension feeder assemblages have received little attention from researchers until the recent interest in the manganese crust resources of the Hawaiian Economic Zone. This has led to necessary research on deep water fauna to assess the potential impact of mining activities on fish stocks and precious corals. The faunal inventories required by the U.S. Environmental Protection Agency to evaluate the possible influence of Hawaii's sewage outfalls on the marine ecosystem involve detailed benthic community analyses. These research programs are adding to our understanding of deeper water benthic communities and serpulid ecology.

## MATERIALS AND METHODS

Sewage outfall sediment samples (0.1 $m^2$) were taken with a modified Van Veen grab from stations adjacent to the Sand Island and Barbers Point outfall diffusers (Nelson, 1986; Nelson et al., 1987). Serpulids were sieved (0.5-mm mesh) from formalin fixed replicate cores (76 mm × 50 mm) for microscopical examination.

Rocks from just north of precious coral beds off Makapuu, S.E. Oahu were collected with the mechanical arm of the submersible MAKALI'I and stored in tubs of isopropyl alcohol. The serpulids were carefully chipped from the rocks and examined with light microscopy after mounting in glycerol and Hoyers medium (which makes the tissue transparent leaving the setae clearly visible). Drawings were made to scale with a camera lucida. Specimens of the *Hydroides, Filogranula, Josephella* and *Rhodopsis* spp. were prepared for scanning electron microscopy (SEM) and viewed with a Cambridge Stereoscan 150 scanning electron microscope. Specimens are deposited at the Bernice P. Bishop

Museum, Honolulu (BPBM), the British Museum of Natural History, London (BMNH) and at the U.S. National Museum, Smithsonian Institution (USNM).

## *Hydroides bannerorum* new species

*Holotype.*—BPBM R 2153.

*Paratypes.*—BMNH ZB 1990.16, ZB 1990.17, 18; BPBM R 2154, USNM 136581.

*Description.*—Tubes are opaque white, thin walled with faint transverse growth lines and without a keel (Fig. 1a). The first formed part of the tube is attached to sand grains, and the mouth was upturned on the terminal erect portion. Tubes measured 5–10 mm in length, 0.5 mm or less in width. Worms removed from the tubes measured 5–6 mm in length, less than 0.5 mm in width. The thorax has 7, 8 or 9 setigers, with collar setae on the first setiger and setae and uncini in the remaining 6, 7 or 8 thoracic setigers. Collar setae are of two types, there are three or four slender capillaries (Fig. 1h, i) and three or four bayonet setae with three stout bosses at the base of the blade and a small denticulate fin (Fig. 1e–g). Remaining thoracic setigers have blade setae (Fig. 1j). Thoracic uncini have two to four rows of teeth and a large round anterior tooth (Fig. 1m, n). There are five to six pairs of slender pinnulate branchiae with smooth tips. A pair of red eyes are evident below the collar. The opercular stalk is smooth and round in section. The operculum is a clear ampulla supporting a crown of 13–17 moveable spines (Fig. 1b, c). A funnel, typical of the genus, that usually supports the crown of spines is not present. Spines are chitinous, light to dark brown with pale tips, and each bears a number of blunt spines along the lateral margins so they appear serrated (Fig. 1d). A pseudo-operculum could not be found. The abdomen has 20–31 setigers (N = 7), with one to four geniculate setae (Fig. 1k) on anterior and middle setigers and one or two capillaries (Fig. 1l) in each fascicle of the last 5 or 6 setigers. Terminal setiger with uncini only. Abdominal uncini (Fig. 1 o–r) are short, each has a large anterior tooth and one or more rows of teeth depending on the position of the uncinus in the row. Abdomen with geniculate setae anteriorly (2–4 in a fascicle), geniculate and capillary setae (1–3 in a fascicle) in more posterior setigers and capillary setae only in the most posterior setigers.

*Remarks.*—*Hydroides bannerorum* shares a similar feature with the genera *Serpula* and *Crucigera* as all three genera have a fluted opercular funnel and a swelling or lobes at the junction of the opercular stalk or on the base of the funnel. The number of thoracic setigers can vary within and among genera in the Serpulinae; *Serpula* may have 7–10, *Crucigera* has 7, *Hydroides* typically has 7 (Bianchi, 1981), although some species of *Hydroides* have 7–10 (Imajima and ten Hove, 1989). The variability in the number of setigers in these specimens may be ontogenic.

*Etymology.*—The specific name is chosen to honor Albert H. (Hank) and Dora May (Dee) Banner for their work on alpheid shrimp and Pacific invertebrates.

*Ecology and Distribution.*—*Hydroides bannerorum* was collected from a depth of 70 m near the Sand Island and Barbers Point outfalls off Oahu (Nelson, 1986; Nelson et al., 1987). It was most abundant at Barbers Point with 26 specimens at the ZID station (Zone of Initial Dilution), one of five of the seven stations where the species was found (Nelson et al., 1987).

## *Josephella marenzelleri* Caullery and Mesnil, 1896

*Material.*—Specimens deposited at BPBM R 2155, USNM 136582.

*Description.*—The tubes (Fig. 2a) measure 10–15 mm in length and less than 0.2 mm in width, are very fragile, white and translucent so that the position of the

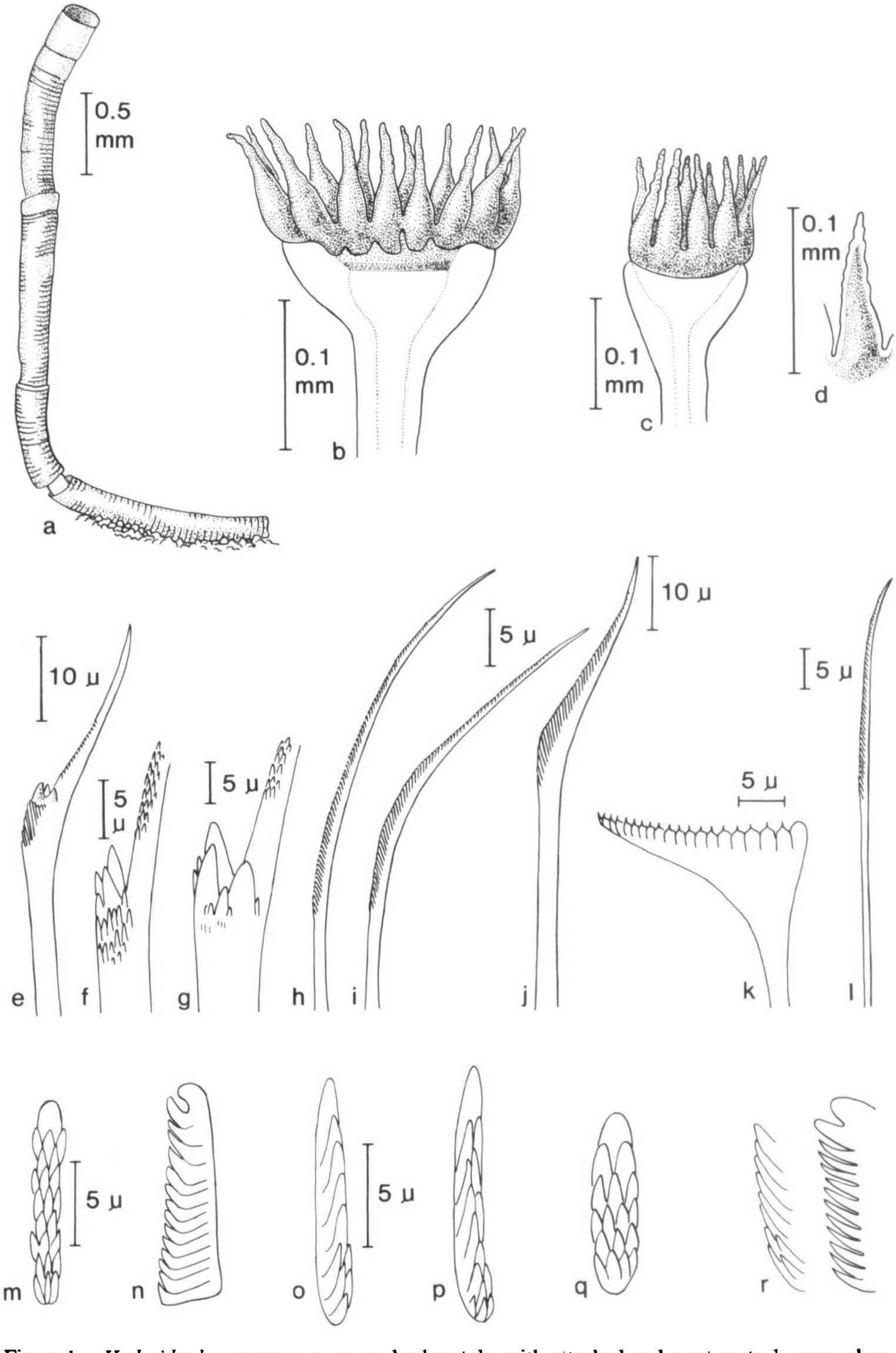


Figure 1. *Hydroides bannerorum* n. sp.: a, broken tube with attached and erect parts; b, operculum with spines extended; c, operculum with closed spines; d, detail of spine; e, lateral view of bayonet seta; f, g, bayonet seta viewed with SEM; h, i, two capillary setae of first thoracic setiger; j, blade seta of thoracic setigers; k, geniculate abdominal seta with SEM; l, abdominal capillary seta; m, anterior thoracic uncinus with SEM, face view; n, thoracic uncinus, lateral view; o, p, q, abdominal uncini, face view; r, abdominal uncinus, lateral views.

worm and operculum are visible through the tube wall. The posterior end of the tube has a lattice-like disc at the point of attachment to the substrate (Fig. 2b). Some tubes contained two worms, probably the result of asexual transverse division. The worms measure 1–2 mm in length and less than 0.2 mm in width. The opercular stalk has paired pinnules (Fig. 2c) like those of the radioles. The ampulla is vesicular (Fig. 2c) with a plate bordered by a chitinous ring (Fig. 2c, d) with approximately 30 thickened radii that support it like ribs. The tips of the radii are connected to form the distal margin of the ring. With SEM the ring resembles a delicate fluted structure (Fig. 2e). The surface of the plate is slightly elevated in the center and is covered with short triangular protrusions (Fig. 2d). There are five thoracic setigers. Collar (Fig. 2f) and thoracic setae are simple blades, and *Apomatus* setae (Fig. 2g) with a scalloped blade with 16 teeth along the margin are present from setiger 3. Thoracic uncini (Fig. 2i) have a hyaline anterior fin with a straight margin, a posterior gouge and many rows (4–5 in the mid-region, 7–10 at the anterior margin) of teeth. Abdominal uncini (Fig. 2j, k) also have many rows of teeth and a straight anterior margin. Abdominal setae are simple capillaries (Fig. 2h).

*Remarks.*—Opercular ribs each have a slight thickening about ⅓ from the base (Fig. 2c) that projects into the chitin between two adjacent ribs. These may strengthen the rim of the plate. Ribs are thicker at the bases and finely pointed at the tips.

*Distribution.*—*Josephella marenzelleri* has probably been overlooked in Hawaii because of its small size. This species was found at a depth of 70 m off Barbers Point (as *Serpula* sp. A in Nelson et al., 1987) and Sand Island (Russo et al., 1988). One hundred and one specimens were collected at Sand Island, 98 of them from the two stations either side of the ZID. Numerically, *Josephella marenzelleri* made up 91% of the suspension feeding community at one of these boundary stations. This species has a widespread distribution associated with rocky substrata, crustose coralline algae, kelps, and as a fouling community component on artificial substrates (Zibrowius, 1968; Bianchi, 1981). In Hawaii it occurs as part of the soft sediment community with the tubes loosely attached to coarse coral sand (grain size 4 phi).

### *Rhodopsis pusilla* Bush, 1905

*Material.*—Specimens deposited at BPBM R 2156.

*Description.*—Delicate white tubes 5 mm or less in length and approximately 0.1 mm in width, with faint transverse growth thickenings around the leading edge of each tube section (Fig. 3a). The mouth is narrower than the rest of the tube and poorly calcified. Brood chambers were not present on any of the specimens examined. Worms occupied a portion of the tube and were less than 0.5 mm in length. The operculum is an ampulla with a spiny flexible plate. The ampulla is thin walled with a central blood mass (Fig. 3b) and a reticulated surface (Fig. 3c). The opercular stalk is smooth and there is a slight swelling where it joins the ampulla. Each spine is triangular with a broad base and pointed apex. Most peripheral spines form a ring around the edge of the plate and these are more slender, slightly curved and sharply pointed in shape. The plate is concave, lower on one side than the other (Fig. 3b), and opposing sides fold towards each other. Folding is due to the flexible nature of the plate which can be flattened with a cover slip, and appears to lack a median crease or hinge line. A pair of reddish-

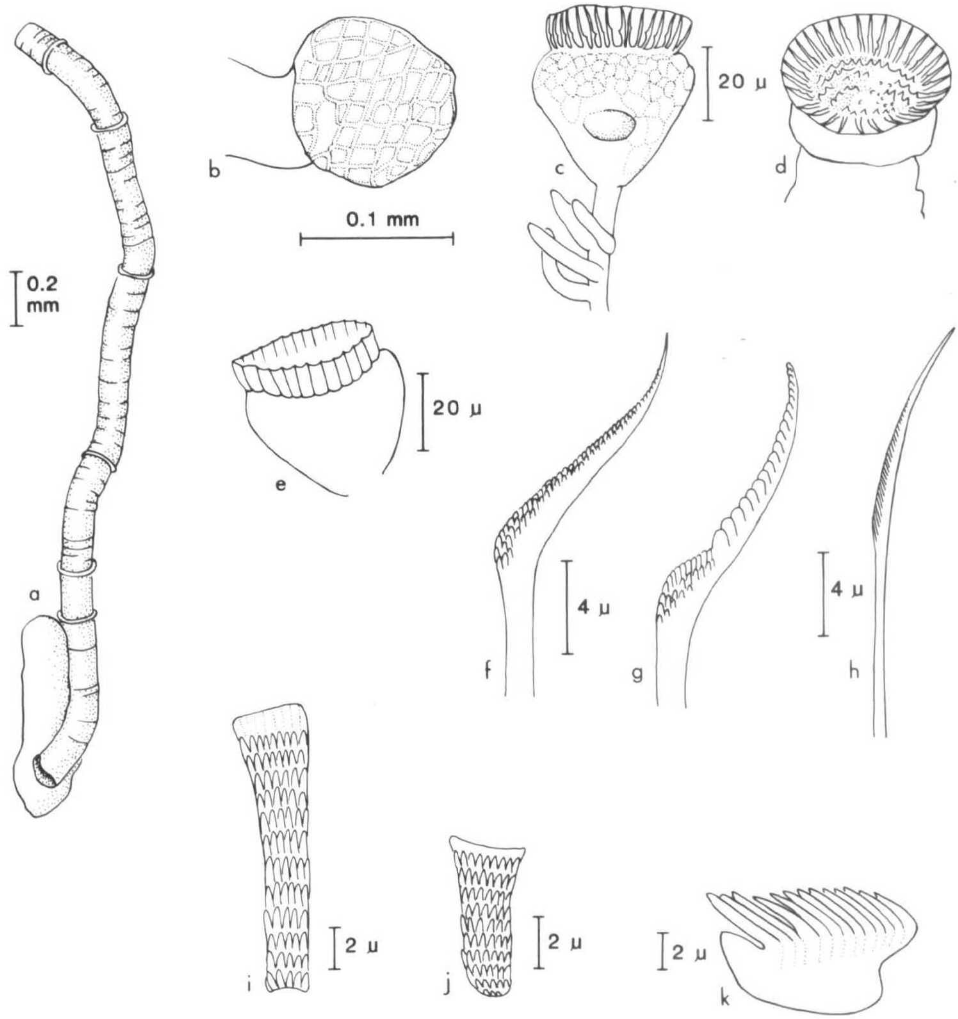


Figure 2. *Josephella marenzelleri* Caullery and Mesnil, 1896: a, tube; b, lattice-like disc of tube attachment; c, lateral view of operculum; d, face view of operculum; e, operculum viewed with SEM; f, collar seta; g, *Apomatus* seta of setiger 3; h, abdominal capillary seta; i, thoracic uncinus; j, abdominal uncinus; k, abdominal uncinus, lateral view.

brown, dorsolateral eyes are present just below the collar. There are no collar setae.

There are four thoracic setigers (N = 6), the first setiger has two or three blade setae (Fig. 3d) and 6–13 uncini, the second, third and fourth setigers have blade and *Apomatus* setae (Fig. 3e). A finely toothed fin at the base of the *Apomatus* blade (Fig. 3e) was more conspicuous on some of the specimens and when viewed with the SEM. The second setiger has three setae, one of which is an *Apomatus* seta, and 6–12 uncini; the third has two blades, one *Apomatus* seta and six to nine uncini, and the fourth has one blade, one *Apomatus* seta and four to nine uncini. The uncini are rasps with a single large anterior tooth and about nine rows of smaller teeth (Fig. 3f, g). Uncini are narrow anteriorly and broadly rounded posteriorly (Fig. 3g).

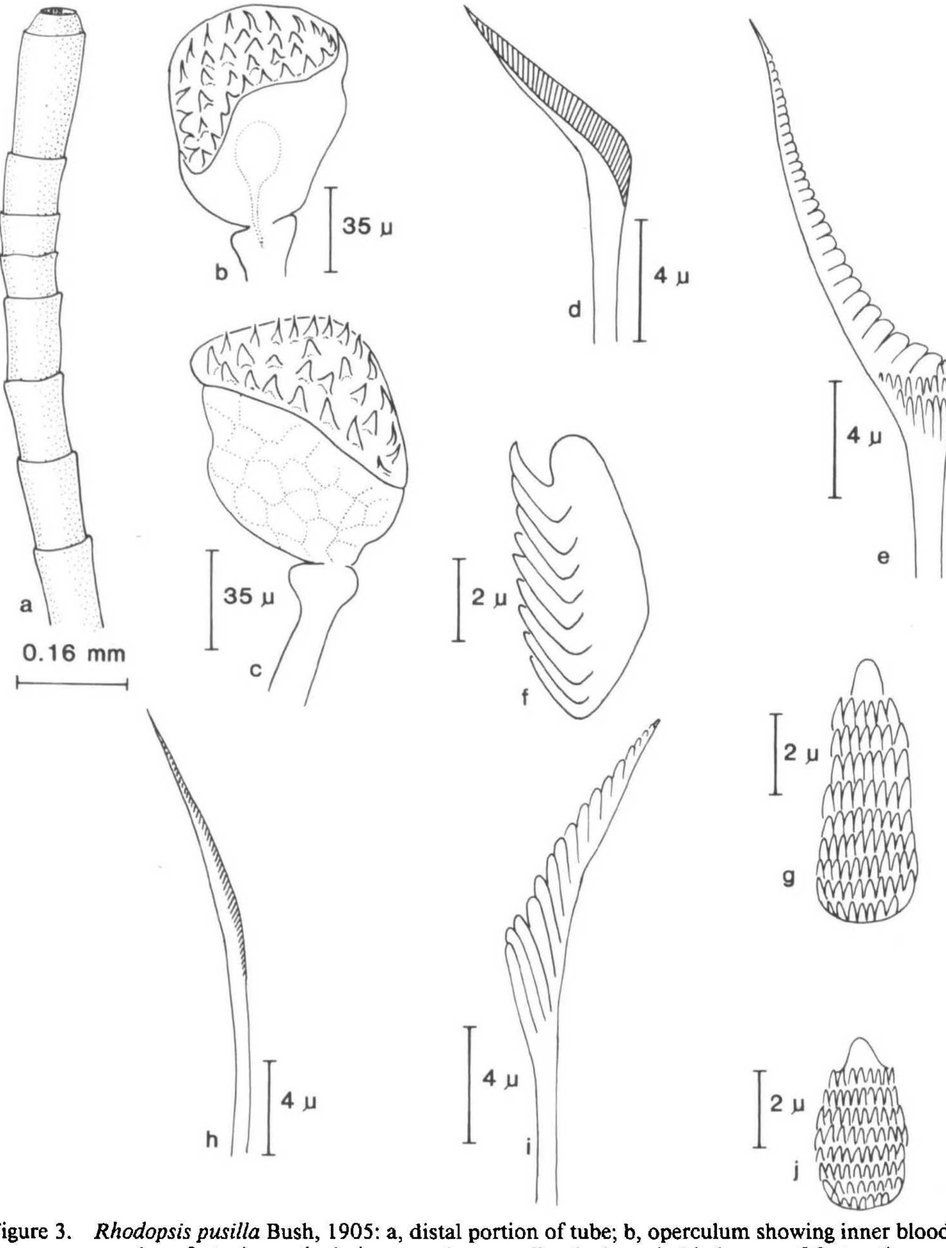


Figure 3. *Rhodopsis pusilla* Bush, 1905: a, distal portion of tube; b, operculum showing inner blood mass; c, operculum featuring reticulations on the ampulla; d, thoracic blade seta of first setiger; e, *Apomatus* seta of second thoracic setiger with SEM; f, edge view of thoracic uncinus; g, thoracic uncinus with SEM; h, abdominal blade seta; i, abdominal geniculate seta; j, abdominal uncinus.

There is a long asetigerous region between the thorax and abdomen which comprised 4–6 setigers in the complete specimens. Setigers 1,2 and 6 each have a single blade seta (Fig. 3h), setigers 3–5 may have two setae, a straight blade and a geniculate seta (Fig. 3i). Setigers 1–5 have three to nine uncini, setiger 6 has four. The abdominal uncini are rasps similar to the thoracic ones, but are shorter and more rounded in shape (Fig. 3j).

*Remarks.*—Specimens closely resemble the figures and description in Ben-Eliahu and ten Hove (1989) and are therefore assigned to *R. pusilla*. The small size and extreme fragility of these specimens made it very difficult to extract whole worms from the sponge they were growing on. The tips of tubes that may have had brood chambers could have been lost or destroyed while removing the worms. The Hawaiian specimens could be juveniles because there were only 4 thoracic and up to 6 abdominal setigers, while material from other locations have 4–6 thoracic and 11–15 abdominal setigers (Ben-Eliahu and ten Hove, 1989). Similarly the absence of brood chambers may indicate the juvenile condition.

Bush (1905) described *Rhodopsis* and distinguished it from other serpulid genera by the absence of collar setae. The Bermuda specimens of *R. pusilla* have 5–6 thoracic setigers. Bush was unable to see the many rows of teeth on the abdominal uncini, and describes them as uniform in width. The Hawaiian specimens have abdominal uncini that are shorter than the thoracic uncini and broadly rounded posteriorly and narrow anteriorly.

*Ecology and Distribution.*—Numerous tubes within the spicular framework of the basal part of a foliaceous demosponge (*Leiodermata* sp.), collected at a 12 m depth in a cave off the Kona coast of Hawaii. *Rhodopsis pusilla* is known from Japan, E. Australia, Indonesia, the Red Sea, Mediterranean, Indian Ocean and under coral heads at the type locality, Bermuda (Ben-Eliahu and ten Hove, 1989; Bush, 1905).

## *Filogranula gracilis* Langerhans, 1884

*Material.*—Specimens deposited at BPBM R 2157.

*Description.*—The tube is opaque, white and triangular in section (Fig. 4a). There is a median row of delicate spines that terminate as a broad triangular spine over the mouth (Fig. 4b). The distal portion of the tube is frequently erect and the mouth is surrounded by five or seven triangular flaps giving a star or petal-like appearance to the end of the tube (Fig. 4c). Earlier tube mouths are evident along the length of the tube as transverse rings of these petalloid spines (Fig. 4d). The tube measures 15–20 mm in length and 2–3 mm in width behind the mouth. The largest specimen measured 3–5 mm in length and 0.2 mm in width. The operculum has a simple, cup-shaped, thin, chitinous plate (Fig. 4e) that appears off-set and asymmetrical in specimens preserved in the tube. The opercular stalk is difficult to observe as it is surrounded by radioles which easily tear when teased apart. There are more than four radioles comprising the branchial crown. There are 7 thoracic setigers. Collar setae are fin and blades (Fig. 4f) with one or two capillary setae (Fig. 4g) per fascicle. Setae of setiger 2 are all simple blades. *Apomatus* setae (Fig. 4h) and simple blades (Fig. 4i) are present in setigers 3–7. Thoracic uncini (visible on 6 setigers) are three to five tooth rows wide and have an anterior peg tooth (Fig. 4j, k). The thoracic membrane extends to between setigers 2 and 3. One specimen with 15 abdominal setigers, each with one broad geniculate seta (Fig. 4m) and a blade seta with coarse teeth (Fig. 4l). Abdominal uncini with an anterior peg and nine rows of teeth four to six teeth wide (Fig. 4n, o).

*Remarks.*—These specimens are assigned to *Filogranula* according to Zibrowius (1972) who placed previously described *Omphalopoma* species in this genus.

*Distribution.*—*Filogranula gracilis* was collected on lava rock from a depth of 330 m off S.E. Oahu at a rocky location north of the Makapuu precious coral beds. Thirty or more tubes (some white, others yellow and damaged) were counted on

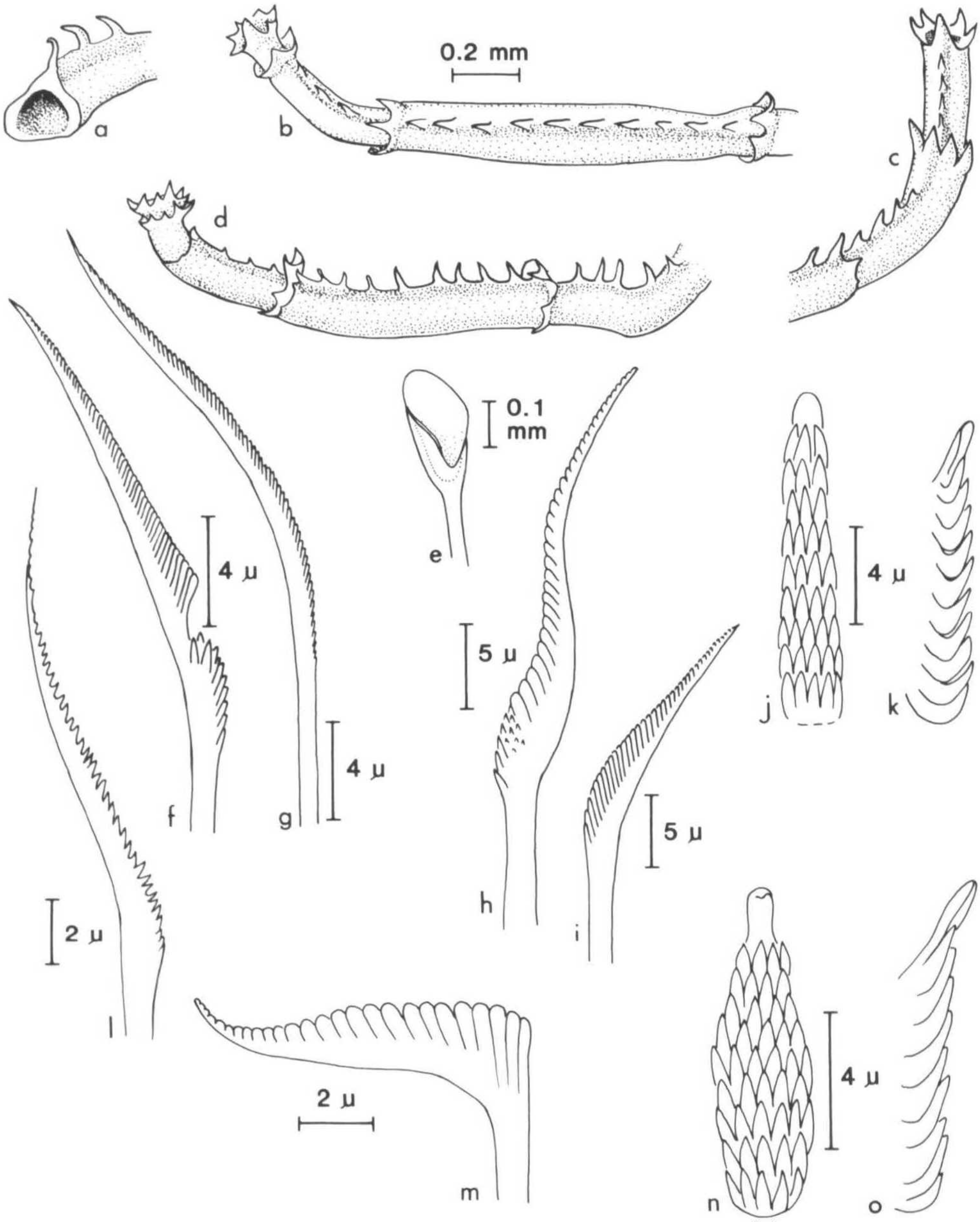


Figure 4. *Filogranula gracilis* Langerhans, 1884: a, tube in section; b, tube with petalloid opening and toothed median ridge; c, erect portion of tube; d, lateral view of tube showing positions of two previous tube mouths; e, opercular plate; f, collar seta; g, capillary seta from first thoracic setiger; h, *Apomatus* seta from setiger 3; i, thoracic blade seta; j, thoracic uncinus; k, lateral view of thoracic uncinus with SEM; l, abdominal blade seta; m, abdominal geniculate seta; n, abdominal uncinus; o, abdominal uncinus, lateral view.

a small piece of rock approximately 25 mm in diameter. *Filogranula gracilis* is known to reproduce asexually by transverse fission in the middle of the abdomen (ten Hove, 1979) which may account for the density of tubes on the rock. Scissiparity is often more frequent than sexual reproduction in extremely small ser-

pulids perhaps because of the high energy cost of producing eggs and the space required to brood larvae (ten Hove, 1979). A single specimen with an intact tube and 6 thoracic setigers was collected just west of the Hawaiian Chain (18°31'N, 175°40'W) by the R.V. VITJAS. The specimen was attached to manganese rock that was trawled from a depth of 1,600-1,900 m (VITJAS Station number 6348-2).

## DISCUSSION

*Hydroides bannerorum* n. sp. and *Josephella marenzelleri* are of interest because they are small and occur on sediments, a habitat atypical of most serpulids which usually attach to hard substrata. The small size of these species and their obvious ability to attach to sand grains and grow away from the substratum suggest that a stable environment exists at these sewage outfall sites. Otherwise these worms would be buried and easily crushed by movement of the upper few millimeters of sand, and/or completely disoriented so that the tube mouth is below the sediment surface. Survival of these worms may be due to their tolerance of physical disturbance in the form of shifting sediments, or because they reproduce frequently and juveniles or larvae are plentiful to start new populations following catastrophic mortality, or it may be assumed that the sediments at the outfall sites are compacted and relatively stable (Nelson, 1986; Nelson et al., 1987).

*Filogranula gracilis* occupies deeper habitats characterized by friable lava rocks, manganese crusts and basalt outcrops. At the Makapuu site this species was associated with two large serpulid species *Vermiliopsis infundibulum* and *Spirobranchus latiscapus* that are characteristic of these depths in Hawaiian waters (Bailey-Brock, 1972), solitary ahermatypic corals (*Cyatheras* sp.) and a spirorbid species. The erect mouths of the delicate spinous tubes suggest that this species lives in protected habitats. These specimens were in cavities and depressions in the rock and therefore sheltered from mechanical damage.

Firm substrata in the form of basalt rocks, ferromanganese crusts and nodules, and stable sediments are appropriate for serpulid settlement. Serpulids respond to sedimentation by forming tube mouths that grow up away from the substrate as shown for some serpulids and spirorbids (Bailey-Brock and Knight-Jones, 1977; ten Hove and Zibrowius, 1987).

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